Bear Creek
Sediment, Turbidity, & Discharge Monitoring Report

no photos

April - August 2003

Mark Story & Cheryl Taylor
Gallatin National Forest
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Introduction

A cooperative water quality monitoring project in Bear Creek was conducted in 2003 to measure discharge, suspended sediment, bedload sediment and discharge in Bear Creek at 8 sites. The objective was to assess changes in water quality in Bear Creek from natural variables and activities including trail and road motorized use, and downstream residential and agricultural activities.

Cooperators included the Gallatin National Forest, numerous Bear Canyon homeowners, Montana DEQ, Montana Water Center, the Gallatin Local Water Quality District, and several other volunteers. This monitoring project is part of a larger water quality monitoring study in Bear Canyon which includes Beneficial Use Determination field work in July of 2003 (Montana DEQ, Gallatin Local Water Quality District, Montana Water Center, Gallatin NF), fish population shocking (Gallatin NF) in October 2003, and a Beneficial Use Determination to be prepared for Bear Creek in the spring of 2004 by the Montana DEQ.

The monitoring of sediment, turbidity, and discharge in Bear Creek was designed to respond to public concerns, primarily Bear Canyon homeowners, about erosion and water quality in Bear Creek due to motorized recreation use, particularly ATV's. This monitoring will be an integral part of the Montana DEQ beneficial use determination of water quality in Bear Creek. This monitoring information will be useful in the completion of the Gallatin NF Travel Management Plan which will select a travel management alternative on National Forest lands in Bear Canyon.

Methods

Eight sites were selected for the Bear Creek sampling. Site selection was designed to sample upstream of most of the motorized impacts then downstream where Trail #440 parallels Bear Creek. The sampling was extended further downstream to include impacts from the Bear Canyon road, residences, changing geomorphic character of the stream, and agricultural activities below the Canyon. The sampling sites include site #1 above the trail 440 crossing, site #2 below Dean Gulch, site #3 at the Gallatin NF boundary, site #4 below the trail fords and slide, site #5 at the trailhead parking lot, site #6 New World Gulch, site #7 about 1 mile below the trailhead below the mouth of the canyon, and site #8 at Bozeman Trail road. All sampling sites are shown on the enclosed map.

Sampling was done during 31 days between April 15 and August 19. Sampling protocols were selected by Mark Story with a training sessions for volunteers on 4/7 and 4/22. Susan McIlroy and Mary Sadowski coordinated the volunteer sampling scheduling. Volunteer samplers included: Susan McIlroy, Mary Sadowski, Shelly Watters, Paul Gaffney, Sara Rustling, Ben Bailey, Gonnie Siebel, Phil Knight, Patty Cramer, Wendi Urie, Richard Urie, Margie Rankin, Joanne Noel, Fran Noel, Tim Haraden, Steve Malmberg, Rick Meis, Robert Hamlin, and Mia Pelt.

Forest Service samplers (on 5 of the dates) included Mark Story, Cheryl Taylor, Taylor Greenup, Wendi Urie, and Bruce Sims. Staff gages (to calibrate the relationship between stage and discharge) were installed at sites #1 and site #5 on 4/17/03. An existing staff gage at the Bozeman Trail road bridge was used at site #8. Sampling by the Forest Service occurred on April 15, 16, April 22nd, May 20, and May 27. All other sampling was done by the volunteer samplers twice weekly from April 26 through June 28 then weekly for July and August. Forest service measurements included discharge (cfs) using USGS pygmy and price AA meters with a Swoffer digital revolutions/seconds counter, suspended sediment (DH 48 wading sampler), bedload sediment (Helly-Smith 3" sampler), and turbidity with a HACH 2100A turbidity meter. The volunteers estimated discharge by measuring a XS at each site then floating 3 sticks through the cross section to get surface velocity and collected sediment samples with DH48's. Stage at sites #1, #5, and #8 was recorded during each sampling event. Cheryl Taylor did all water quality laboratory analysis at the Gallatin NF water lab in Bozeman using a gravimetric filtration method for suspended sediment with a Mettler H72 balance to 0.00001 g. Bedload sediment was weighed with an Acculab V-1200 balance and bedload discharge calculated by factoring in sampling area and time. Turbidity was measured with a HACH 2100A turbimeter using freshly calibrated Gelex standards. All water quality data is enclosed in Appendix 1.

Bear Canyon Site 1 on July 22, 2003

Ford between Sites #3 and #4 on May 27, 2003.

Bear Creek Site #8 on July 24, 2003, about 0.25 mile above the Bozeman Trail road bridge.

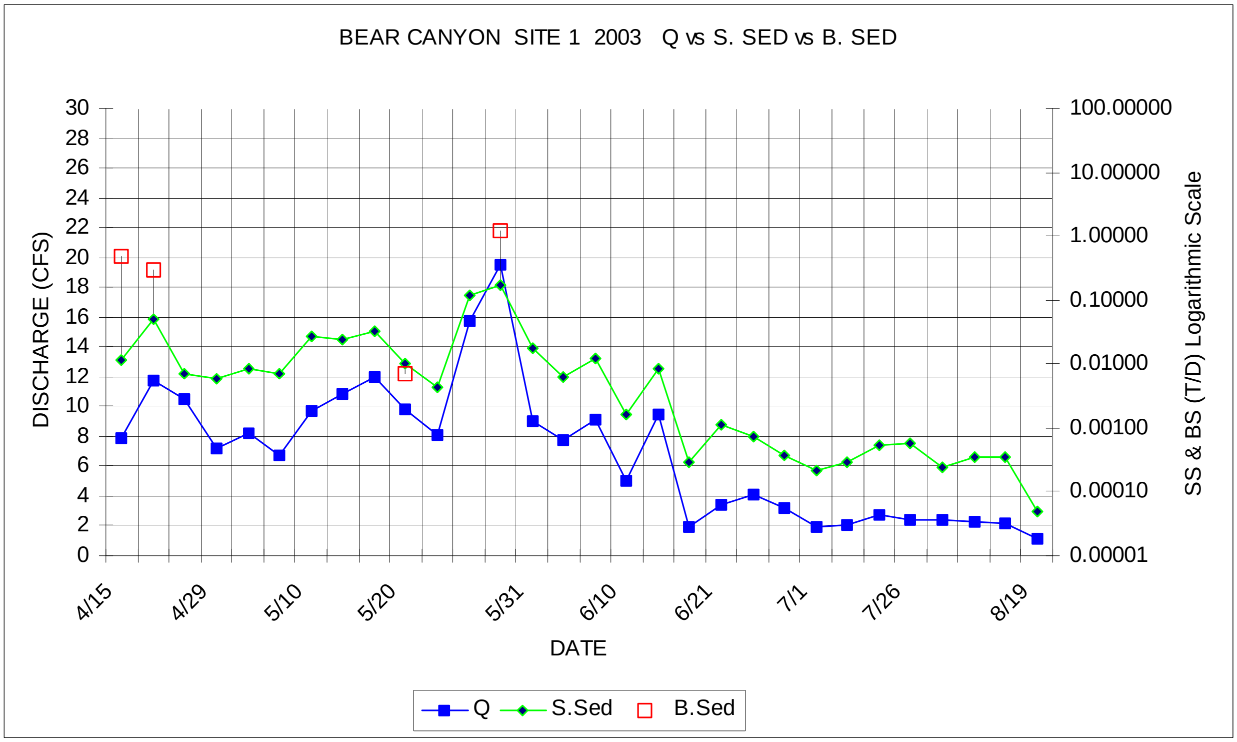
Staff gage and discharge measurement at Site 5 on April 22, 2003.

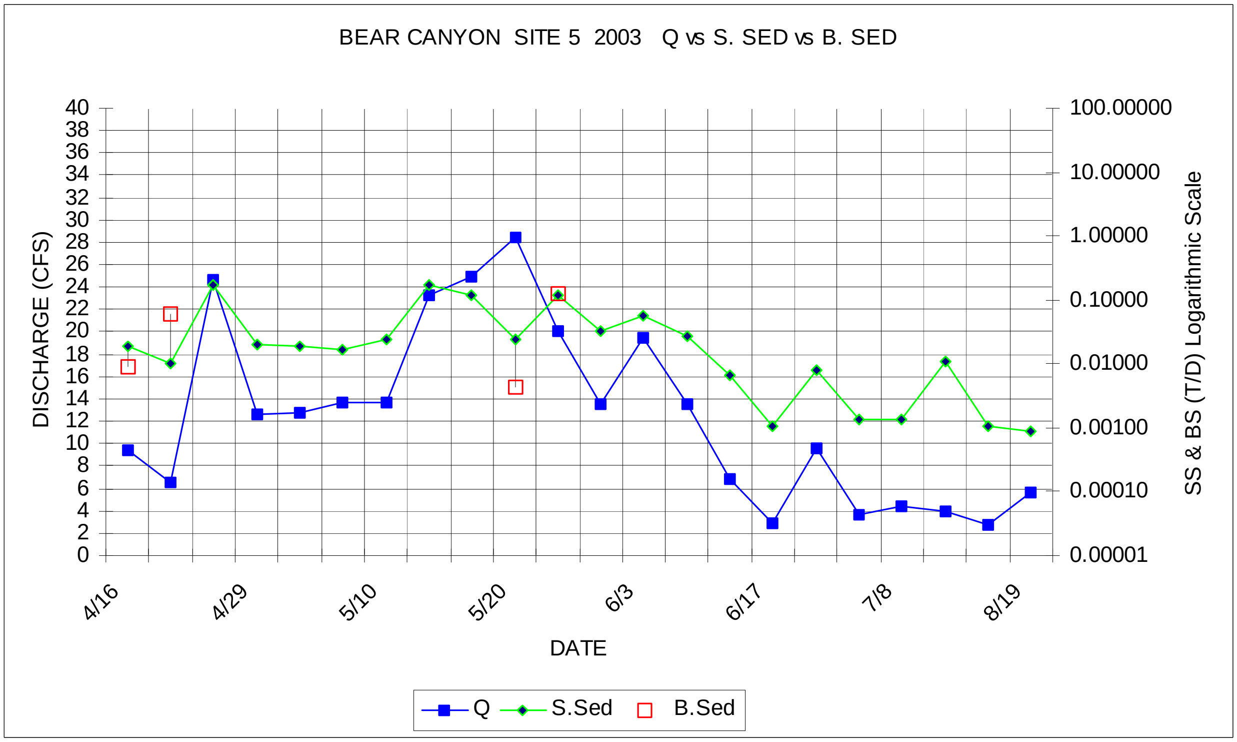
Results

All data from the 2003 Bear Creek monitoring is enclosed in Appendix 1. Measured suspended sediment, bedload sediment, turbidity, and discharge means were tabulated for all sampling dates (4/15 to 8/19, 2003).

Site	Discharge CFS	Turbidity NTU	Suspended Sediment mg/L	Bedoad Sediment Tons/day
1	6.94	10.2	0.52	0.50
2	10.1	10.3	0.76	0.82
3	12.9	12.4	0.81	0.15
4	13.4	13.1	1.82	0.076
5	12.6	10.6	0.82	0.049
6	7.49	6.1	0.22	0.031
7	19.9	10.9	1.49	0.11
8	22.0	15.5	4.16	0.064

Discharge in 2003 was greatest during the snowmelt runoff period of April and May (Appendix 1) then declined steadily in June and sharply in July and August when the weather was warm and dry. Peak flows included 12 cfs at site #1 on 5/17, 22.4 cfs at site #2 on 5/24, 28 cfs at site #3 on 4/26, 32.2 cfs at site #4 on 5/17, 28.4 cfs at site #5 on 5/20, 18.1 cfs site #6 on 5/13, 46.5 cfs at site #7 on 5/24, and 50.6 cfs at site #8 on 5/24. By August 19 stream flows had declined to 1.18 cfs at site #1, 0.5 cfs at site #2, 0.74 cfs at site #3, 4.89 cfs at site #4, 5.56 cfs at site #5, 0.74 cfs site #6, 3.77 cfs at site #7, and 2.08 cfs at site #8. Average discharge, as shown in the table above, generally increased downstream with a drop at Bear Creek site #5 and site #6 (New World Gulch). Average turbidity generally increased in the downstream direction with reductions at sites #5, #6, and #7. Suspended sediment had a very similar pattern to turbidity. Bedload data analysis is limited by only 5 sampling dates (4/15, 4/16, 4/22, 5/20, and 5/27) but indicates the highest bedload concentrations were at sites 1-3.





Suspended sediment loadings were closely related to stream discharge at all of the sites with the highest streamflow and sediment yields during the snowmelt runoff period in April and May.

The NRCS estimates that the Gallatin River watershed, which includes Bear Creek, had about a 95% of average snowpack on 4/1/03 and 5/1/03, and reduced to about 80% of average on 6/1/03. This indicates that snowmelt runoff discharge was near average during the early phases of runoff but was less than average during the last part of runoff in June. Preliminary NOAA data indicated that for the June-August period, Bozeman had only 2.52 inches of precipitation which was only 53% if the average 4.74 inches. during the period. The drier than average summer precipitation also occurred in Bear Canyon with very limited localized rain events and stormflow flushing of the watershed.

Statistical analysis of the data (Ponce, 1980; McDonald, 1991) were run using Microsoft Excel spreadsheet linear regressions, and Excel statistical analysis for "t" tests. Of primary statistical question were paired comparisons ("above vs below") to test for statistically significant sediment and turbidity changes between sites. A summary of results include:

1. Paired "t" tests of suspended sediment between site means (day n site X vs day n site Y) showed no statistically significant differences (2 tailed test at 0.05 alpha level) between sites 1 vs 2, 2 vs 3, 3 vs 4, 4 vs 5, 6 vs 7, and 7 vs 8. Site 6 (New World Gulch) had a significantly lower sediment mean (0.05 alpha level) than Bear Canyon site # 5.

2. Paired "t" tests of turbidity between site means (day n site X vs day n site Y) showed no statistically significant differences (2 tailed test at 0.05 alpha level) between sites 1 vs 2, 2 vs 3, 3 vs 4, and 4 vs 5. Site 6 (New World Gulch) had a significantly lower turbidity mean than Bear Canyon sites # 5 and #7.

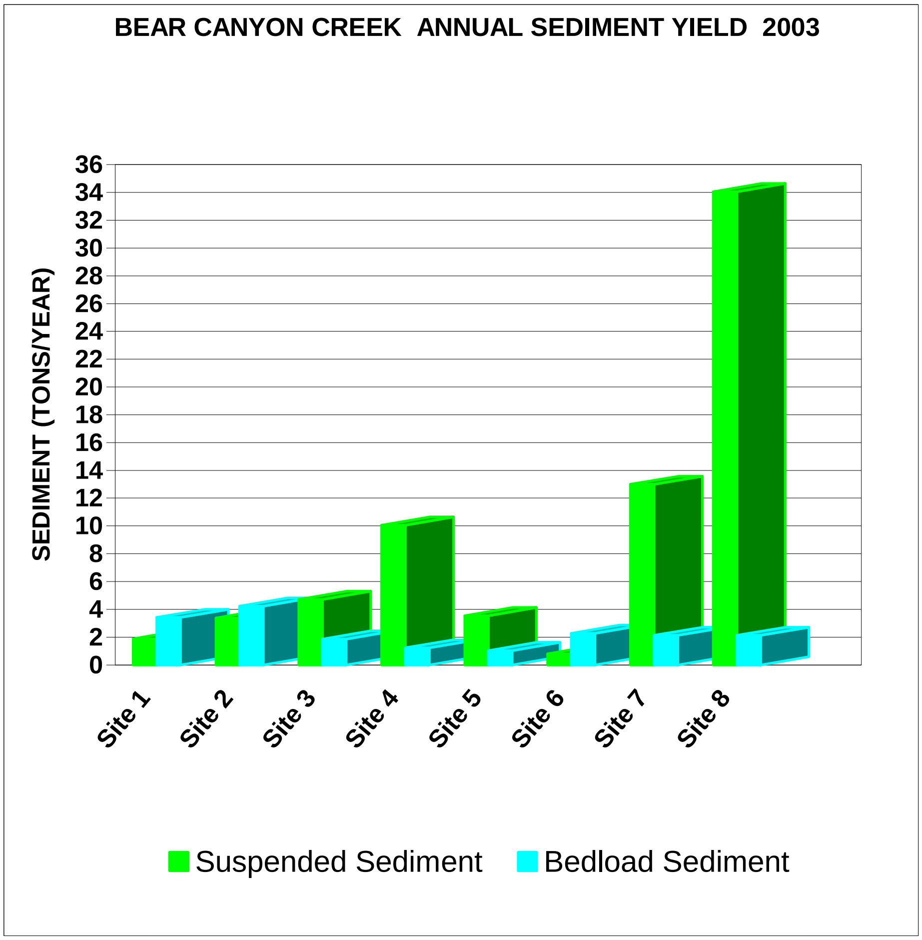
3. Linear regressions (sediment rating curves) of suspended sediment and log discharge showed good correlation between these variables at sites 1,2, 3, 6, and 7 with moderate correlation at sites #5 and #8. Poor correlation between sediment and discharge occurred at site #4.

Site 1:	log suspended sediment =	0.52 log discharge	+ 1.08	R2=0.89
Site 2:	log suspended sediment =	0.45 log discharge	+ 1.12	R2=0.78
Site 3:	log suspended sediment =	0.49 log discharge	+ 1.19	R2=0.64
Site 4:	log suspended sediment =	0.25 log discharge	+ 1.05	R2=0.20
Site 5:	log suspended sediment =	0.53 log discharge	+ 1.14	R2=0.51
Site 6 :	log suspended sediment =	1.11 log discharge	- 1.83	R2=0.67
Site 7:	log suspended sediment =	0.33 log discharge	+ 1.21	R2=0.65
Site 8:	log suspended sediment =	0.35 log discharge	+ 1.13	R2=0.57

Total loadings of suspended and bedload sediment, total sediment (suspended + bedload), and ratio of bedload to suspended sediment were calculated for each site assuming that baseflow days not sampled could be represented by the lowest measured suspended and bedload samples. This assumption is reasonable for suspended sediment but probably over-estimates annual bedload discharge.

Site	1	2	3	4	5	6	7	8
watershed size mile2	6.03	7.46	8.88	9.35	9.83	6.50	18.87	19.48
suspended sediment tons/year	1.88	3.38	4.71	10.06	3.54	0.79	12.99	34.06
bedload sediment tons/year	3.41	4.22	1.85	1.22	1.02	2.28	2.12	2.12
total sediment tons/year	5.28	7.60	6.56	11.28	4.57	3.07	15.11	36.18
suspended sediment tons/mile2/year	0.31	0.45	0.54	1.08	0.36	0.12	0.69	1.75
total sediment tons/mile2/year	0.88	1.02	0.74	1.21	0.46	0..47	0.80	1.86
ratio of bedload sediment to suspended sediment	1.82	1.25	0.39	0.12	0.29	2.14	0.16	0.06

The suspended sediment and bedload sediment yields are primarily related to discharge variation. At all sites suspended sediment loading was highest during the snowmelt period in April and May but quickly declined in June. Bedload sediment was only measured during snowmelt runoff in April and May but exceeded suspended sediment in tons/day at sites 1, 2, and 6 during snowmelt runoff. In general the percentage of bedload in total sediment yield declined from the upper sites to the lower sites.



The above graph of annual suspended sediment yield shows that measured bedload sediment was highest at sites 1 and 2 but must be qualified since only 4 bedload samples were taken per site. The suspended sediment data indicate that suspended sediment generally increased in the downstream direction with the notable exception at site #5 where suspended sediment was reduced. Site #6 (New World Gulch) had the lowest suspended sediment (as validated by the t tests previously mentioned).

The distribution of measured sediment levels between sites is probably due to series of natural and man-causes factors. The upper site #1 is a relatively low gradient (0.65%), high sediment deposition site with extensive upstream raw sloughing banks. Some of the bank sloughing is due to cattle grazing but most appears to be natural. This site is "energy limited" in that sufficient sediment is stored in the steam channel and is mobilized as streamflow increases. Most of the bedload measured at site #1 was fine textured silt material. Site #2 is also below a relatively unstable section of Bear Creek. Bear Creek Trail #440 is sufficiently separated (to the west) of Bear Creek between sites # 1 and 2 so that snowmelt and rain stormflow runoff of the trail does not directly discharge into Bear Creek. Between sites #2 and #3 the Bear Creek stream channel becomes steeper (gradient of 1.73% at site #3) and coarser textured which evidently decreases the fine bedload (silt and sand) loading. Trail #440 (on National Forest land) parallels Bear Creek with a ford between the sites. The section of trail in the vicinity of the ford appears to be a sediment source to Bear Creek during stormflow periods.

Between site #3 and site #4 (which is on State of Montana DSL land) Trail #440 is very close to Bear Creek with several areas where stormflows directly discharge to the Creek. A large semi-active slide on the west side of BAER Canyon forces 2 fords of Bear Creek within a few hundred feet. The slump periodically sloughs into Bear Creek and the fords can be quite reactive to crossings by ATV's, motorcycles, and less frequently by horses and mountain bikes. Site #4 is about 100' downstream of the lower ford. The highest suspended sediment measurements at site 4 on were measured on July 8 and July 26 when ATV and motorcycles were noted fording Bear Creek above the sampling sites.

Road section between site #2 and site#3 where road drainage can directly discharge into Bear Creek (May 27, 2003)

Between sites #4 and #5 the Bear Creek stream channel has more separation from Trail #440 and is also steeper (gradient of 3.29% at site #5) and coarser textured. The slight reduction in bedload sediment and substantial reduction of suspended sediment between sites #4 and #5 is probably due primarily to the change to a coarser textured stream type.

New World Gulch site #6 has similar bedload discharge to sites #3, #7, and #8 but substantially lower suspended sediment discharge than all of the other sites.   Trail #50 up New World Gulch has limited sediment impacts on the stream although some naturally unstable stream segments occur about 1 mile above the confluence with Bear Creek.

Bear Creek sites #7 and #8 have slightly increased bedload (as compared to site #5) but large increases in suspended sediment. The increase at site #7 is probably due largely to finer textured (and therefore more erodible) stream channel between site #5 and #7, stormflow from roads and residences, and some agricultural impacts. Gradient at site #8 was measured at 1.05%. Bear Creek site #8 has the highest suspended sediment loading (nearly 3 times as high as all other sites). The high sediment loading at site #8 is probably due to a combination of fine textured streambanks, agricultural use (concentrated cattle grazins along Bear Creek between sites #7 and #8), and irrigation return flows. The highest (of all Bear Creek sites) suspended sediment concentration (54.35 mg/L) and turbidity (96 NTU's) occurred on June 14 at site #8.

Agricultural impacts to Bear Creek about 0.5 miles above site #8 on May 27, 2003. This area is a substantial sediment source to lower Bear Creek due to bank sloughing and direct stormflow during rain events.

The 2003 Bear Creek monitoring measured lower sediment levels that other Northern Gallatin Range streams monitoring on the Gallatin NF with similar protocols and the same equipment. Goose Creek was monitored in 1989 associated with the Bear Chestnut Timber Sale. Goose Creek total sediment (tons/mile^2/year) varied from 4.2 to 16.4 with maximum suspended concentrations of 37.0 to 81.6 mg/L. Hyalite Creek was monitored in 1991 at Langor Campground and at the Forest Boundary with total sediment yields of 12.5 and 17.5 tons/mile^2 year. Hyalite Creek had a maximum suspended sediment concentrations of 33.1 to 56.9 mg/L and maximum turbidity readings of 10 to 22 NTU. Bear Creek in 2003 had total sediment yield of 0.38 tons/mile^2/year at site 6, from 0.73 to 1.2 at the other sites except for 1.85 tons/mile^2/year at site 8.

Turbidity at the Bear Creek sites (which was measured with the same HACH 2100A turbidimeter as Goose Creek and Hyalite Creek) had average turbidity of 6.1 NTU at New World site #6 and 10.2 to 15.5 NTU in the Bear Creek sites. The highest measured turbidity in Bear Creek was at site #4 (60 NTU on 7/26) probably associated with a vehicle crossing and site #8 (96 NTU on 6/14), which was likely associated with upstream agricultural activity. Hyalite Creek had average turbidity of 3.3 and 5.1 NTU and maximum turbidity readings of 10 to 22 NTU. Goose Creek had an average turbidity of 14.6 to 21.5 NTU and maximum turbidity of 45 to 56 NTU. Geologically (Ramsey et.al., 1978) Bear Creek is more similar to Goose Creek (mainly Paleozoic and Mesozoic sediments) than Hyalite Creek which is dominated by Tertiary volcanics in the headwaters. Hyalite Creek turbidity is also influenced by releases from Hyalite Reservoir, which reduces turbidity.

Conclusions

1. The Bear Creek stream system discharge and sediment monitoring in 2003 was a cooperative effort which was largely made possible by the volunteer samplers, listed in the Methods section, who collected samples on a total of 26 days.

2. Monitoring results indicate that Bear Creek sediment and turbidity is affected by a complex variety of natural and man caused factors, which are difficult to separate The main variable affecting sediment and turbidity appears to be the naturally unstable and fine textured nature of much of the Bear Creek system. The steepest part of the stream system (as measured at sites #5 and #6) had reduced sediment levels due partially to more coarse textured stream channels. In the lower sections #7 and #8 Bear Creek meanders through finer textured channel areas with naturally higher levels of sediment delivery.

3. The 2003 data could have been more diagnostic of the potential impacts of recreation use on the Trail # 440 system if more stormflow flushing occurred. Mid-June through the end of the sampling period on August 19 was a relatively dry period with very limited localized intensive rainstorms and stormflow discharge. The measured increases (although not statistically significant) in suspended sediment and turbidity between sites #2 and #3 and #3 and #4 are probably due to increased sediment deposition from Trail #440. Sediment is introduced during stormflow periods and mobilized during fording of the stream by motorized use (ATV's and motorcycles) at the ford between site #2 and #3 and particularly the fords between sites #3 and #4.

4. The sediment increases at site #7 is likely due to the finer textured nature of the stream channel noted previously and stormflow from roads and residences between sites #5 and #7, and some agricultural impacts.

5. The most definitive sediment and turbidity change in Bear Creek occurs between sites #7 and #8. The natural sediment increase due to fine textured and erodible streambanks between the 2 sites appears to be greatly accelerated by agricultural impacts.

6. Measured sediment levels in Bear Canyon were lower than 2 previously monitoring drainages in the Northern Gallatin Range (Goose Creek and Hyalite Creek). Turbidity levels in Bear Creek were higher than Hyalite Creek (which has less erosive geological parent material and reservoir control) but less than Goose Creek which has similar parent material to Bear Creek.

Literature Cited

McDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. EPA/910/9-91-001. Seattle, WA.

Ponce, S.L., 1980. Statistical Methods Commonly Used in Water Quality Data Analysis, U.S.F.S., WSDU, Fort Collins, Colorado.

Ramsey, B., C. Davis, and C. Montagne. 1978. Geologic Overview of the Gallatin National Forest. Bozeman, Montana.